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Applicant(s) : Dai Nippon Printing Co., Ltd.

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[DOCUMENT]	Specification	1
[DOCUMENT]	Drawings	1
[DOCUMENT]	Abstract Sheet	1

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[NAME OF DOCUMENT] Specification

[TITLE OF THE INVENTION] Microreactor for Hydrogen Production and Production Method Thereof

[CLAIMS]

[Claim 1]

A microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a metal substrate having a microchannel portion on one surface thereof, a heater provided on the other surface of said metal substrate via an insulating film, a catalyst supported on said microchannel portion, and a cover member having a feed material inlet and a gas outlet and joined to said metal substrate so as to cover said microchannel portion.

[Claim 2]

A microreactor according to claim 1, wherein said metal substrate is one of an Al substrate, a Cu substrate, and a stainless substrate.

[Claim 3]

A microreactor according to claim 1, wherein said insulating film is a metal oxide film formed by anodically oxidizing said metal substrate.

[Claim 4]

A microreactor according to claim 3, wherein said metal oxide film is also provided in said microchannel portion.

[Claim 5]

A microreactor according to claim 3 or 4, wherein said metal substrate is an Al substrate.

[Claim 6]

A microreactor according to any one of claims 1 to 5, wherein a heater protective layer is provided so as to cover said heater while exposing only electrodes of said heater.

[Claim 7]

A production method of a microreactor for obtaining hydrogen gas by reforming a feed material, characterized by comprising:

a step of forming a microchannel portion on one surface of a metal substrate;

a step of anodically oxidizing said metal substrate to form an insulating film in the form of a metal oxide film;

a step of providing a heater on said metal oxide film on a surface, where said microchannel portion is not formed, of said metal substrate;

a step of applying a catalyst to said microchannel portion; and

a step of joining a cover member formed with a feed material inlet and a gas outlet to said metal substrate so as to cover said microchannel portion.

[Claim 8]

A production method of a microreactor for obtaining hydrogen gas by reforming a feed material,

characterized by comprising:

a step of forming a microchannel portion on one surface of a metal substrate;

a step of providing an insulating film on a surface, where said microchannel portion is not formed, of said metal substrate;

a step of providing a heater on said insulating film;

a step of applying a catalyst to said microchannel portion; and

a step of joining a cover member formed with a feed material inlet and a gas outlet to said metal substrate so as to cover said microchannel portion.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[TECHNICAL FIELD OF THE INVENTION]

The present invention relates to a microreactor for use in a reformer for hydrogen production and, in particular, to a microreactor for obtaining hydrogen gas by reforming a feed material such as methanol, and a production method of such a microreactor.

[0002]

[PRIOR ART]

[PATENT DOCUMENT 1] Laid-open Unexamined Patent Publication No. 2002-252014

In recent years, attention has been paid to using hydrogen as fuel because of no generation of global warming

gas such as carbon dioxide in terms of the global environmental protection, and of the high energy efficiency. Particularly, attention has been paid to fuel cells because they can directly convert hydrogen to electric power and enable the high energy conversion efficiency in the cogeneration system utilizing generated heat. The fuel cells have been hitherto employed under the particular conditions such as in the space development and the ocean development. Recently, however, the development has advanced toward using them for automobile and household distributed power supplies, and fuel cells for portable devices have also been developed.

[0003]

Among the fuel cells, the fuel cell for producing electricity by electrochemically reacting hydrogen gas obtained by reforming hydrocarbon fuel such as natural gas, gasoline, butane gas, or methanol, and oxygen in air is composed of a reformer for producing hydrogen gas by, in general, steam reforming hydrocarbon fuel, a fuel cell body for producing electricity, and so forth.

In the reformer for obtaining hydrogen gas by steam reforming methanol or the like as a feed material, a Cu-Zn catalyst is mainly used to carry out steam reforming of the feed material by an endothermic reaction. In the industrial fuel cell, since the startup and stop are not frequently carried out, a temperature fluctuation of the reformer is not liable to occur. However, in the fuel cell

for automobile or portable device, since the startup and stop are carried out frequently, the reformer is required to rise up quickly (a time for reaching a steam reforming temperature of methanol is short) upon starting up from the stopped state.

[0004]

On the other hand, particularly for the portable device, reduction in size of the fuel cell is essential so that reduction in size of the reformer has been studied variously. For example, there has been developed a microreactor having a silicon substrate or a ceramic substrate formed with a microchannel portion and carrying a catalyst in this microchannel portion (Patent Document 1).

[0005]

[PROBLEM TO BE SOLVED BY THE INVENTION]

In the conventional microreactor, however, there has been a problem that the heat utilization efficiency is low so that the rising speed of the reformer is slow upon starting up from the stopped state. There has also been a problem that processing by a micromachine, etc. are required and therefore the production cost is high.

Therefore, the present invention has been made for solving the foregoing problems. An object thereof is to provide a microreactor that enables a small-sized and highly-efficient reformer for hydrogen production, and a production method that can easily produce such a microreactor.

[0006]

[MEANS FOR SOLVING THE PROBLEMS]

For accomplishing such an object, the present invention is configured such that a microreactor for obtaining hydrogen gas by reforming a feed material, comprises a metal substrate having a microchannel portion on one surface thereof, a heater provided on the other surface of said metal substrate via an insulating film, a catalyst supported on said microchannel portion, and a cover member having a feed material inlet and a gas outlet and joined to said metal substrate so as to cover said microchannel portion.

As another mode of the present invention, it is configured such that said metal substrate is one of an Al substrate, a Cu substrate, and a stainless substrate.

As another mode of the present invention, it is configured such that said insulating film is a metal oxide film formed by anodically oxidizing said metal substrate, or that said metal oxide film is also formed in said microchannel portion. Further, it is configured such that said metal substrate is an Al substrate.

As another mode of the present invention, it is configured such that a heater protective layer is provided so as to cover said heater while exposing only electrodes of said heater.

[0007]

Further, the present invention is configured such

that a production method of a microreactor for obtaining hydrogen gas by reforming a feed material, comprises a step of forming a microchannel portion on one surface of a metal substrate; a step of anodically oxidizing said metal substrate to form an insulating film in the form of a metal oxide film; a step of providing a heater on said metal oxide film on a surface, where said microchannel portion is not formed, of said metal substrate; a step of applying a catalyst to said microchannel portion; and a step of joining a cover member formed with a feed material inlet and a gas outlet to said metal substrate so as to cover said microchannel portion.

Further, the present invention is configured such that a production method of a microreactor for obtaining hydrogen gas by reforming a feed material, comprises a step of forming a microchannel portion on one surface of a metal substrate; a step of providing an insulating film on a surface, where said microchannel portion is not formed, of said metal substrate; a step of providing a heater on said insulating film; a step of applying a catalyst to said microchannel portion; and a step of joining a cover member formed with a feed material inlet and a gas outlet to said metal substrate so as to cover said microchannel portion.

According to the foregoing present invention, since the metal substrate has a higher thermal conductivity and a smaller heat capacity, heat is transmitted from the heater to the applied catalyst with a high efficiency.

[0008]

[MODE FOR CARRYING OUT THE INVENTION]

Hereinbelow, embodiments of the present invention will be described with reference to the drawings.

Microreactor

Fig. 1 is a perspective view showing one embodiment of the microreactor of the present invention, and Fig. 2 is an enlarged longitudinal sectional view of the microreactor shown in Fig. 1, taken along line II-II. In Figs. 1 and 2, the microreactor 1 of the present invention comprises a metal substrate 2, a microchannel portion 3 formed on one surface 2a of the metal substrate 2, an insulating film 4 in the form of a metal oxide film formed on the inside of the microchannel portion 3 and on both surfaces 2a and 2b and side surfaces 2c of the metal substrate 2, a heater 5 provided on the surface 2b of the metal substrate 2 via the insulating film 4, a catalyst C supported on the microchannel portion 3, and a cover member 8 joined to the metal substrate 2 so as to cover the foregoing microchannel portion 3. The heater 5 is formed with electrodes 6 and 6, and a heater protective layer 7 having electrode opening portions 7a and 7a for exposing the electrodes 6 and 6 is provided so as to cover the heater 5. Further, the foregoing cover member 8 is provided with a feed material inlet 8a and a gas outlet 8b.

[0009]

Fig. 3 is a perspective view showing the side,

where the microchannel portion 3 is formed, of the metal substrate 2 of the microreactor 1 shown in Fig. 1. As shown in Fig. 3, the microchannel portion 3 is formed so as to leave comb-shaped ribs 2A and 2B and has a shape that is continuous from an end portion 3a to an end portion 3b. By locating the feed material inlet 8a of the cover member 8 at the end portion 3a and the gas outlet 8b at the end portion 3b, there is formed a flow path that is continuous from the feed material inlet 8a to the gas outlet 8b.

For the metal substrate 2 forming the microreactor 1 of the present invention, there can be used such metal that can form the metal oxide film (insulating film 4) by anodic oxidation. As such metal, there can be cited, for example, Al, Si, Ta, Nb, V, Bi, Y, W, Mo, Zr, Hf, or the like. Among these metals, particularly Al is preferably used in terms of processing suitability, properties such as a heat capacity and a thermal conductivity, and a unit price. The thickness of the metal substrate 2 can be suitably set taking into account the size of the microreactor 1, properties such as a heat capacity and a thermal conductivity of metal to be used, the size of the microchannel portion 3 to be formed, and so forth. For example, it can be set within a range of about 50 to 2000μm.

[0010]

The formation of the metal oxide film (insulating film 4) by anodic oxidation on the metal substrate 2 can be implemented by, in the state where the metal substrate 2 is

connected to an anode as an external electrode, immersing the metal substrate 2 in an anode oxidizing solution so as to confront a cathode and energizing it. The thickness of the metal oxide film (insulating film 4) can be set within a range of, for example, about 5 to 150μm.

The microchannel portion 3 formed on the metal substrate 2 is not limited to the shape as shown in Fig. 3, but can be formed into a desirable shape like one wherein an amount of the catalyst C supported on the microchannel portion 3 increases and the flow path length in which a feed material contacts with the catalyst C is prolonged. Normally, the depth of the microchannel portion 3 can be set within a range of about 100 to 1000μm, the width thereof can be set within a range of about 100 to 1000μm, and the flow path length thereof can fall within a range of about 30 to 300mm.

[0011]

In the present invention, since the insulating film 4 in the form of the metal oxide film is formed also on the inside of the microchannel portion 3, a applying amount of the catalyst C is increased to enable stable catalyst applying due to a surface structure of the metal oxide film having microholes.

As the catalyst C, it is possible to use a known catalyst that has conventionally been employed for steam reforming.

The heater 5 forming the microreactor 1 of the

present invention is for supplying heat required for steam heating of the feed material, which is an endothermic reaction, and it is possible to use therefor a material such as carbon paste, nichrome (Ni-Cr alloy), W (tungsten), or Mo (molybdenum). The heater 5 can have a shape like one that is obtained by, for example, drawing a fine line having a width of about 10 to 200μm over the whole of a region on the metal substrate surface 2b (insulating film 4) corresponding to a region where the microchannel portion 3 is formed.

[0012]

Such a heater 5 is formed with the electrodes 6 and 6 for energization. The electrodes 6 and 6 for energization can be formed using a conductive material such as Au, Ag, Pd, or Pd-Ag.

The heater protective layer 7 has the electrode opening portions 7a and 7b for exposing the foregoing electrodes 6 and 6 and is disposed so as to cover the heater 5. The heater protective layer 7 can be formed of, for example, photosensitive polyimide, polyimide varnish, or the like. The thickness of the heater protective layer 7 can be suitably set taking into account a material to be used and so forth. For example, it can be set within a range of about 2 to 25μm.

[0013]

For the cover member 8 forming the microreactor 1 of the present invention, an Al alloy, a Cu alloy, a

stainless material, or the like can be used. The thickness of the cover member 8 can be suitably set taking into account a material to be used and so forth. For example, it can be set within a range of about 20 to 200μm. The feed material inlet 8a and the gas outlet 8b of the cover member 8 are provided so as to be located at both end portions 3a and 3b of the flow path of the microchannel portion 3 formed on the metal substrate 2.

[0014]

Fig. 4 is a longitudinal sectional view, corresponding to Fig. 2, showing another embodiment of the microreactor of the present invention. In Fig. 4, the microreactor 1' of the present invention comprises a metal substrate 2', a microchannel portion 3 formed on one surface 2'a of the metal substrate 2', an insulating film 4' formed on the other surface 2'b of the metal substrate 2', a heater 5 provided on the surface 2'b of the metal substrate 2' via the insulating film 4', a catalyst C supported on the microchannel portion 3, and a cover member 8 joined to the metal substrate 2' so as to cover the foregoing microchannel portion 3. The heater 5 is formed with electrodes 6 and 6, and a heater protective layer 7 having electrode opening portions 7a and 7a for exposing the electrodes 6 and 6 is provided so as to cover the heater 5. Further, the foregoing cover member 8 is provided with a feed material inlet 8a and a gas outlet 8b.

[0015]

Such a microreactor 1' is the same as the foregoing microreactor 1 except that the metal member 2' and the insulating layer 4' are different and that the metal oxide film (insulating layer 4) is not formed in the microchannel portion 3, and therefore, the same constituent members are assigned the same member numerals to omit description thereof.

As the metal substrate 2' forming the microreactor 1' of the present invention, use can be made of any of an Al substrate, a Cu substrate, a stainless substrate, and so forth. The thickness of the metal substrate 2' can be suitably set taking into account the size of the microreactor 1', properties such as a heat capacity and a thermal conductivity of metal to be used, the size of the microchannel portion 3 to be formed, and so forth. For example, it can be set within a range of about 50 to 2000μm.

[0016]

The insulating film 4' formed on the surface 2'b of the metal substrate 2' can be formed of, for example, polyimide, ceramic (Al_2O_3, SiO_2), or the like. The thickness of such an insulating film 4' can be suitably set taking into account properties of a material to be used and so forth. For example, it can be set within a range of about 1 to 30μm.

The microreactor 1, 1' of the present invention as described above uses the metal substrate 2, 2' having a higher thermal conductivity and a smaller heat capacity as

compared with a silicon substrate or a ceramic substrate, and therefore, heat is transmitted from the heater 5 to the applied catalyst C with a high efficiency, so that there is enabled a reformer for hydrogen production wherein the rising is fast upon starting up from the stopped state and the utilization efficiency of the input power to the heater is high.

The foregoing embodiments of the microreactors are only examples, and the present invention is not limited thereto.

[0017]

Production Method of Microreactor

Figs. 5 and 6 are process diagrams for describing one embodiment of the microreactor producing method of the present invention.

In Figs. 5 and 6, description will be made using the foregoing microreactor 1 as an example. In the production method of the present invention, a microchannel portion 3 is first formed on one surface 2a of a metal substrate 2 (Fig. 5(A)). This microchannel portion 3 can be formed by forming a resist having a predetermined opening pattern on the surface 2a of the metal substrate 2, and etching the metal substrate 2 to leave comb-shaped ribs 2A and 2B by wet etching using the resist as a mask, which can make processing by a micromachine unnecessary. As a material of the metal substrate 2 that is used, there can be cited Al, Si, Ta, Nb, V, Bi, Y, W, Mo, Zr, Hf, or the

like which enables anodic oxidation in the next anodic oxidation process.

[0018]

Then, the metal substrate 2 formed with the microchannel portion 3 is anodically oxidized to form a metal oxide film (insulating film 4) on the whole surfaces including the inside of the microchannel portion 3 (Fig. 5(B)). The formation of this metal oxide film (insulating film 4) can be implemented by, in the state where the metal substrate 2 is connected to an anode as an external electrode, immersing the metal substrate 2 in an anode oxidizing solution so as to confront a cathode and energizing it.

Then, a heater 5 is provided on the metal oxide film (insulating film 4) of a surface 2b, where the microchannel portion 3 is not formed, of the metal substrate 2, and further, electrodes 6 and 6 for energization are formed (Fig. 5(C)). The heater 5 can be formed using a material such as carbon paste, nichrome (Ni-Cr alloy), W, or Mo. As a method of forming the heater 5, there can be cited a method of forming it by screen printing using a paste containing the foregoing material, a method of forming an applied film using a paste containing the foregoing material, then patterning it by etching or the like, a method of forming a thin film by the vacuum deposition method using the forgoing material, then patterning it by etching or the like, or another.

[0019]

On the other hand, the electrodes 6 and 6 for energization can be formed using a conductive material such as Au, Ag, Pd, or Pd-Ag. For example, they can be formed by screen printing using a paste containing the foregoing conductive material.

Then, a heater protective layer 7 is formed on the heater 5 so as to expose the electrodes 6 and 6 (Fig. 5(D)). The heater protective layer 7 can be formed using a material such as polyimide or ceramic (Al_2O_3, SiO_2). For example, it can be formed in a pattern having electrode opening portions 7a and 7a by screen printing using a paste containing the foregoing material.

[0020]

Then, a catalyst C is applied to the microchannel portion 3 (Fig. 6(A)). This catalyst applying can be implemented by immersing the surface 2a, where the microchannel portion 3 is formed, of the metal substrate 2 in a desired catalyst solution.

Then, the metal substrate 2 is polished to expose the surface 2a thereof (Fig. 6(B)), thereafter, a cover member 8 is joined to the metal substrate surface 2a to thereby obtain the microreactor 1 of the present invention (Fig. 6(C)). For the cover member 8, an Al alloy, a Cu alloy, a stainless material, or the like can be used. The joining of the cover member 8 to the metal substrate surface 2a can be carried out by, for example, diffusion

bonding, or the like. Upon the joining, positioning is carried out so that a feed material inlet 8a and a gas outlet 8b provided in the cover member 8 coincide with both end portions of a flow path of the microchannel portion 3 formed on the metal substrate 2.

[0021]

Figs. 7 and 8 are process diagrams for describing another embodiment of the microreactor producing method of the present invention.

In Figs. 7 and 8, description will be made using the foregoing microreactor 1' as an example. In the production method of the present invention, a microchannel portion 3 is first formed on one surface 2'a of a metal substrate 2' (Fig. 7(A)). As the metal substrate 2', it is possible to use any of an Al substrate, a Cu substrate, a stainless substrate, or the like. The formation of the microchannel portion 3 can be implemented like the foregoing formation of the microchannel portion 3 onto the metal substrate 2.

Then, an insulating film 4' is formed on a surface 2'b, where the microchannel portion 3 is not formed, of the metal substrate 2' (Fig. 7(B)). The insulating film 4' can be formed using, for example, polyimide, ceramic (Al_2O_3, SiO_2), or the like. The formation of the insulating film 4' can be implemented, for example, by the printing method such as screen printing using a paste containing the foregoing insulating material, or by forming a thin film by

the vacuum film forming method such as sputtering or vacuum deposition using the foregoing insulating material and curing it.

[0022]

Then, a heater 5 is provided on the insulating film 4', and further, electrodes 6 and 6 for energization are formed (Fig. 7(C)). The formation of such a heater 5 and electrodes 6 and 6 can be implemented like that in the foregoing production method of the microreactor 1.

Then, a heater protective layer 7 is formed on the heater 5 so as to expose the electrodes 6 and 6 (Fig. 7(D)). The formation of this heater protective layer 7 can be implemented like that in the foregoing production method of the microreactor 1.

Then, a catalyst C is applied to the microchannel portion 3 (Fig. 8(A)). This catalyst applying can be implemented by immersing the surface 2'a, where the microchannel portion 3 is formed, of the metal substrate 2' in a desired catalyst solution.

[0023]

Then, the metal substrate 2' is polished to expose the metal substrate surface 2'a (Fig. 8(B)), thereafter, a cover member 8 is joined to the metal substrate surface 2'a to thereby obtain the microreactor 1' of the present invention (Fig. 8(C)). The joining of the cover member 8 can be carried out like that in the foregoing production method of the microreactor 1.

In the microreactor producing method of the present invention as described above, since the metal substrate is used, the formation of the microchannel portion does not require the micromachine processing, but can be easily implemented by a low-priced processing method such as etching to thereby enable reduction in production cost of the microreactor.

The foregoing embodiments of the microreactor producing methods are only examples, and the present invention is not limited thereto.

[0024]

[EXAMPLE]

Now, the present invention will be described in further detail showing more specific examples.

An Al substrate (250mm x 250mm) having a thickness of 1000μm was prepared as a base member, and a photosensitive resist material (OFPR produced by Tokyo Ohka Kogyo Co., Ltd.) was applied (film thickness 7μm (dried)) to both surfaces of the Al substrate by the dip method. Then, on the resist film on the side, where a microchannel portion was to be formed, of the Al substrate, there was disposed a photomask having a shape in which stripe-shaped light-shielding portions each having a width of 1500μm projected (projecting length 30mm) alternately from right and left at pitches of 2000μm. Then, the resist film was exposed via the photomask and developed using a sodium bicarbonate solution. As a result, on one surface of the

Al substrate, there was formed a resist pattern in which stripe-shaped opening portions each having a width of 500μm were arrayed at pitches of 2000μm, and the adjacent stripe-shaped opening portions were alternately continuous with each other at their end portions.

[0025]

Then, using the foregoing resist pattern as a mask, the Al substrate was subjected to etching under the following condition. This etching was for forming a microchannel portion by half etching from the one surface of the Al substrate, and a time required for the etching was three minutes.

(Etching Condition)

· Temperature : 20°C

· Etching Liquid (HCl) Concentration : 200g/L
(one liter containing pure water and
200g of 35% HCl dissolved therein)

[0026]

After the foregoing etching process was finished, the resist pattern was removed using a sodium hydroxide solution and washing was carried out. As a result, on the one surface of the Al substrate, there was formed a microchannel portion (flow path length 300mm) wherein stripe-shaped microchannels each having a width of 1000μm, a depth of 650μm, and a length of 30mm were formed at pitches of 2000μm so as to be alternately continuous with each other at end portions of the adjacent microchannels

(as shown in Fig. 3).

Then, the foregoing Al substrate was connected to an anode as an external electrode, immersed in an anode oxidizing solution (4% oxalic acid solution) so as to confront a cathode, and energized under the following condition, to thereby obtain an aluminum oxide thin film formed as an insulating film. The thickness of the formed aluminum oxide thin film was measured by an ellipsometer, and the result was about 30μm.

(Anodic Oxidation Condition)

· Bath Temperature : 25°C

· Voltage : 25V (DC)

· Current Density : $100A/m^2$

[0027]

Then, on the aluminum oxide thin film, where the microchannel portion was not formed, of the Al substrate, a paste for heater having the following composition was printed by screen printing, then cured at 200°C to form a heater. The formed heater had a shape in which a fine line having a width of 100μm was drawn around on the Al substrate at line intervals of 100μm so as to cover the whole of a region (35mm x 25mm) corresponding to a region where the microchannel portion was formed.

(Composition of Paste for Heater)

· Carbon Powder	···	20 weight parts
· Fine Powder Silica	···	25 weight parts
· Xylene Phenol Resin	···	36 weight parts

· Butyl Carbitol ··· 19 weight parts

[0028]

Further, using a paste for electrode having the following composition, electrodes (0.5mm x 0.5mm) were formed at predetermined two portions of the heater by screen printing.

(Composition of Paste for Electrode)

· Silver-plated Copper Powder ··· 90 weight parts

· Phenol Resin ··· 6.5 weight parts

· Butyl Carbitol ··· 3.5 weight parts

[0029]

Then, using a paste for protective layer having the following composition, a heater protective layer (thickness 20μm) was formed on the heater by screen printing so as to expose the two electrodes formed on the heater.

(Composition of Paste for Protective Layer)

· Resin Concentration ··· 30 weight parts

· Silica Filler ··· 10 weight parts

· Lactone Solvent ··· 60 weight parts

(penta-1, 4-lactone)

[0030]

Then, the side, where the microchannel portion was formed, of the Al substrate was immersed (10 minutes) in a catalyst aqueous solution having the following composition, then was subjected to a dry/reduction treatment at 250°C for six hours, thereby applying a catalyst in the

microchannel portion.

(Composition of Catalyst Aqueous Solution)

· Al ··· 41.2 weight%

· Cu ··· 2.6 weight%

· Zn ··· 2.8 weight%

[0031]

Then, the side, where the microchannel portion was formed, of the Al substrate was polished by alumina powder to thereby expose the Al surface. Then, as a cover member, an Al plate having a thickness of 100μm was diffusion bonded to the Al substrate surface under the following condition. This Al plate was provided with two opening portions (a feed material inlet and a gas outlet: size of each opening portion 0.6mm x 0.6mm), and positioning was carried out so that the opening portions coincided with both end portions of a flow path of the microchannel portion formed on the Al substrate.

(Diffusion Bonding Condition)

· Atmosphere : Under Vacuum

· Bonding Temperature : 300°C

· Bonding Time : 8 Hours

Consequently, a microreactor of the present invention was obtained.

[0032]

[ADVANTAGES OF THE INVENTION]

According to the foregoing present invention, since the metal substrate forming the microreactor has a

higher thermal conductivity and a smaller heat capacity as compared with a silicon substrate or a ceramic substrate, heat is transmitted from the heater to the applied catalyst with a high efficiency, so that there is enabled a reformer for hydrogen production wherein the rising is fast upon starting up from the stopped state and the utilization efficiency of the input power to the heater is high. Further, the formation of the microchannel portion on the metal substrate does not require the processing by a micromachine, but can be easily implemented by a low-priced processing method such as etching to thereby enable reduction in production cost of the microreactor.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Fig. 1 is a perspective view showing one embodiment of a microreactor of the present invention.

Fig. 2 is an enlarged longitudinal sectional view of the microreactor shown in Fig. 1, taken along line II-II.

Fig. 3 is a perspective view showing the side, where a microchannel portion is formed, of a metal substrate of the microreactor shown in Fig. 1.

Fig. 4 is a longitudinal sectional view, corresponding to Fig. 2, showing another embodiment of a microreactor of the present invention.

Fig. 5 is process diagrams for describing one embodiment of a microreactor producing method of the present invention.

Fig. 6 is process diagrams for describing one

embodiment of a microreactor producing method of the present invention.

Fig. 7 is process diagrams for describing another embodiment of a microreactor producing method of the present invention.

Fig. 8 is process diagrams for describing another embodiment of a microreactor producing method of the present invention.

[DESCRIPTION OF THE REFERENCE NUMERALS]

1,1'	microreactor
2,2'	metal substrate
3	microchannel portion
4	insulating film (metal oxide film)
4'	insulating film
5	heater
6	electrode
7	heater protective layer
8	cover member
C	catalyst

[NAME OF DOCUMENT] Drawing

[Fig.1]

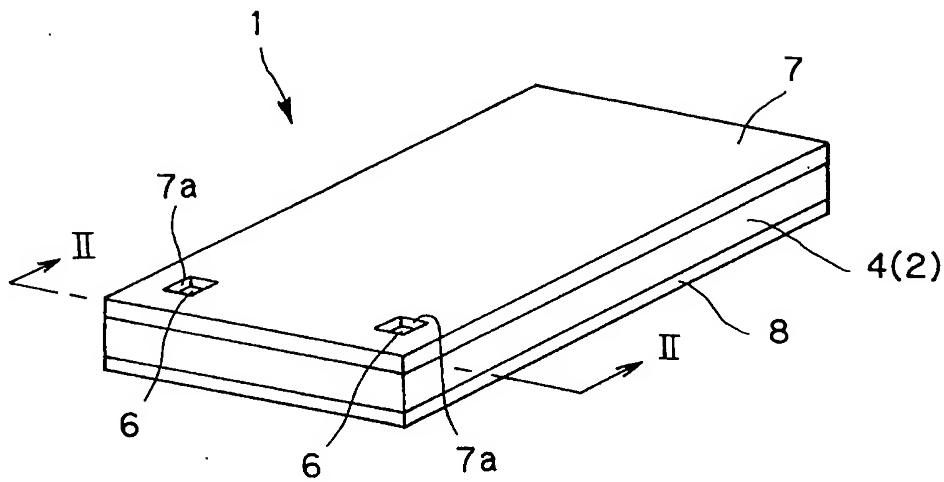


FIG.1

[Fig.2]

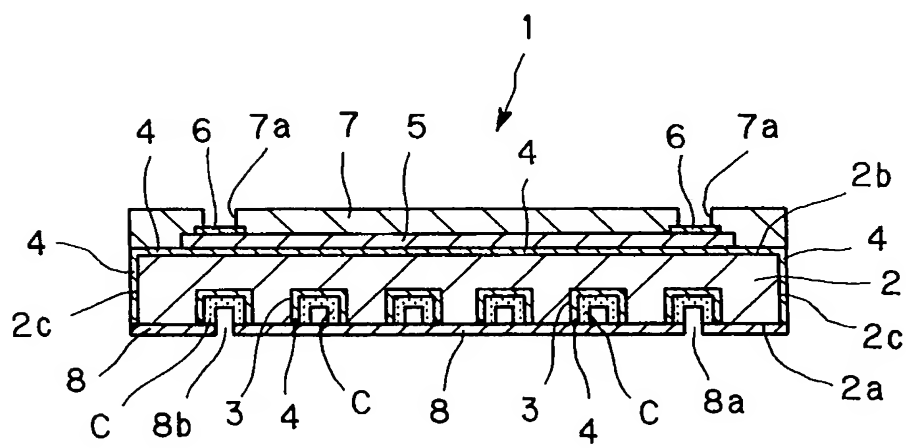


FIG.2

[Fig.3]

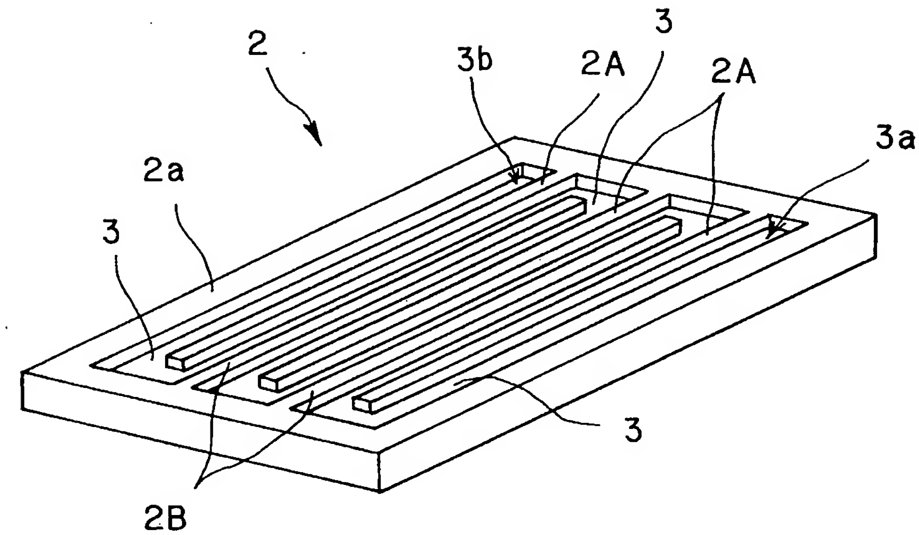


FIG.3

[Fig.4]

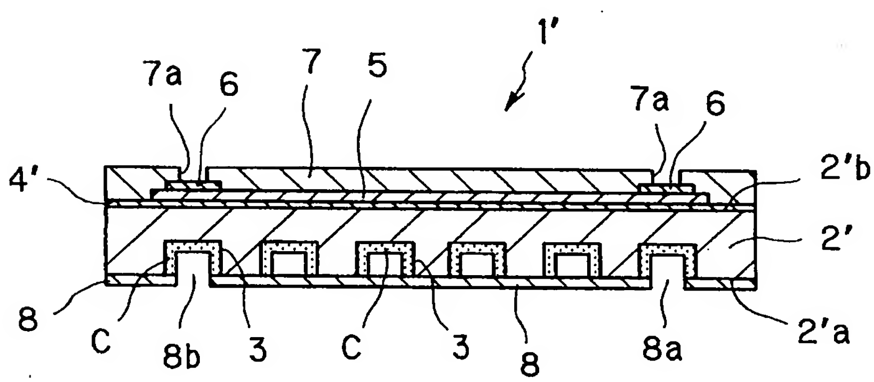


FIG.4

[Fig.5]

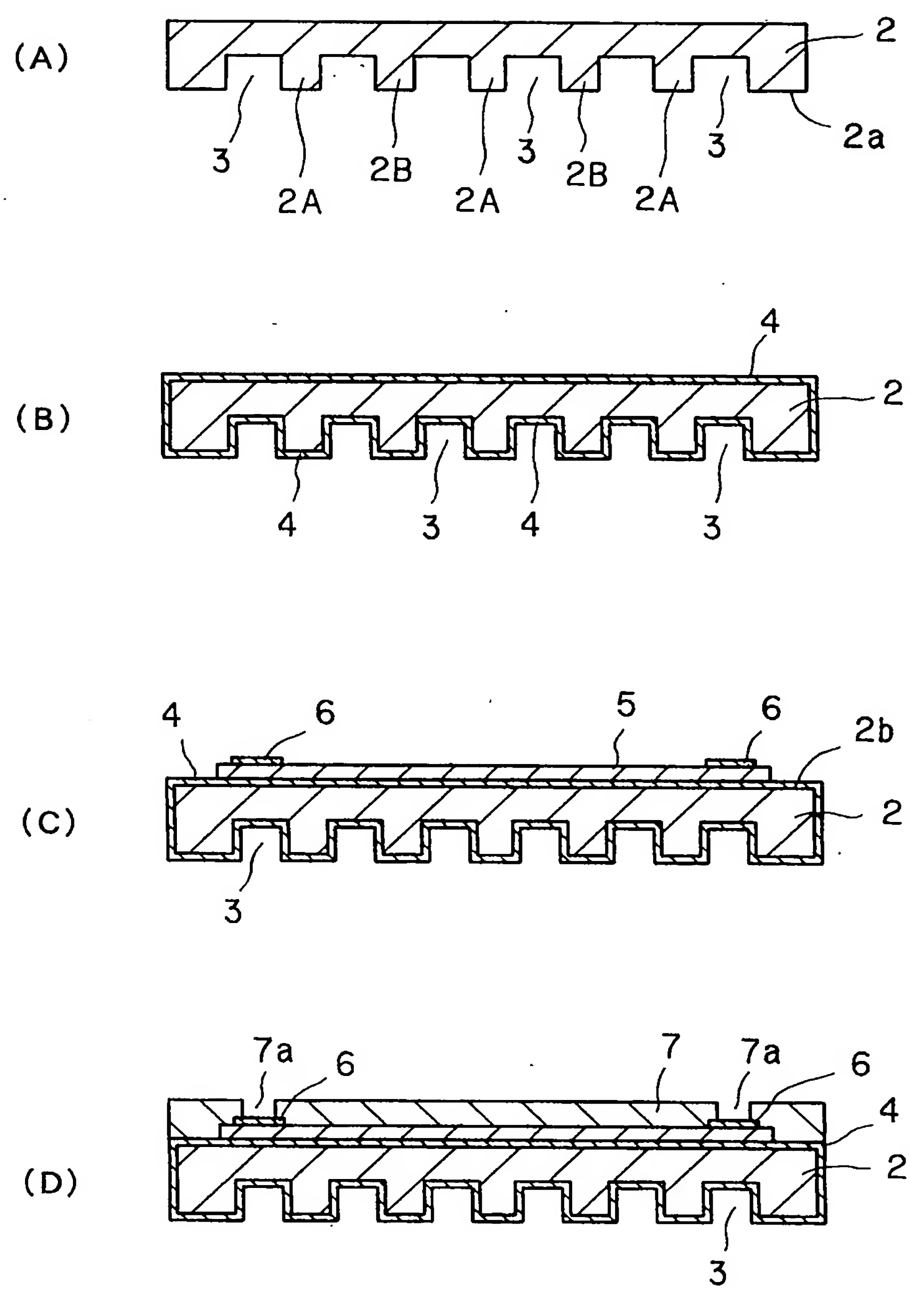


FIG.5

[Fig.6]

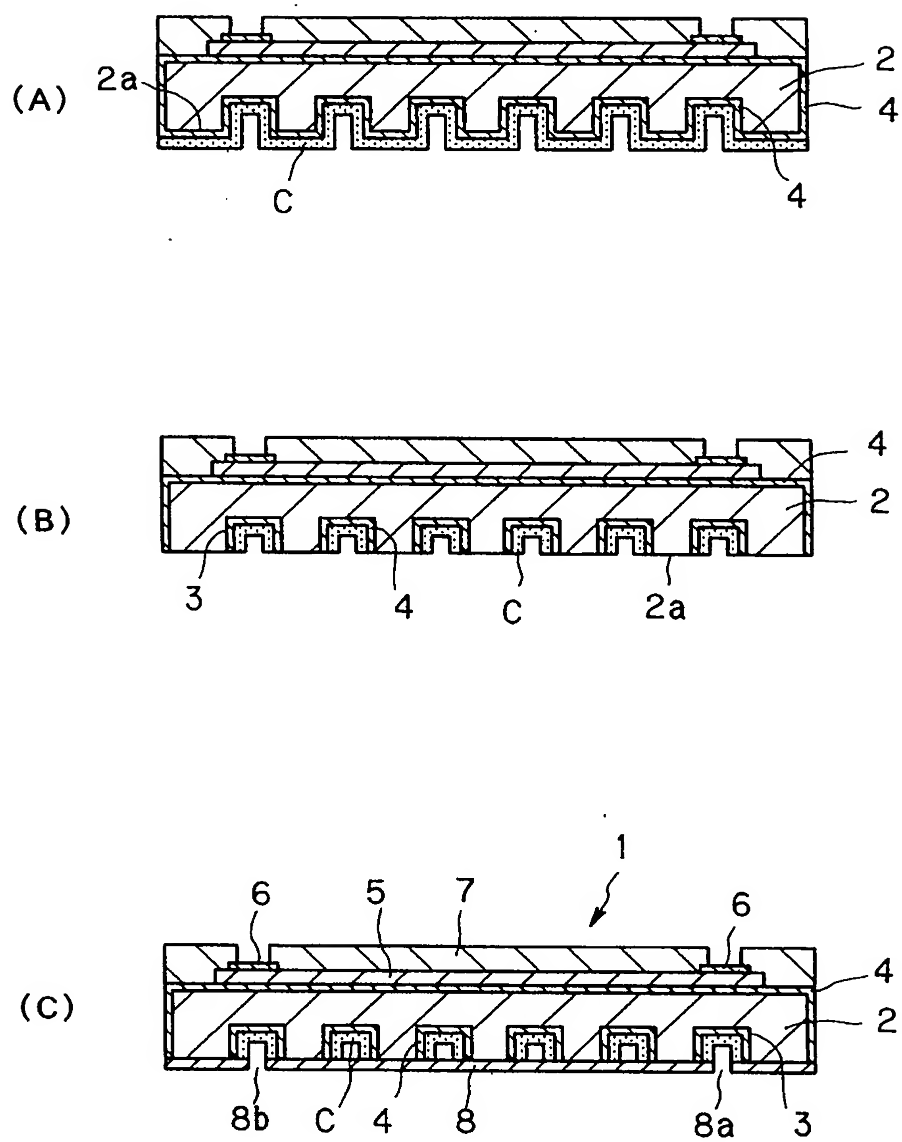
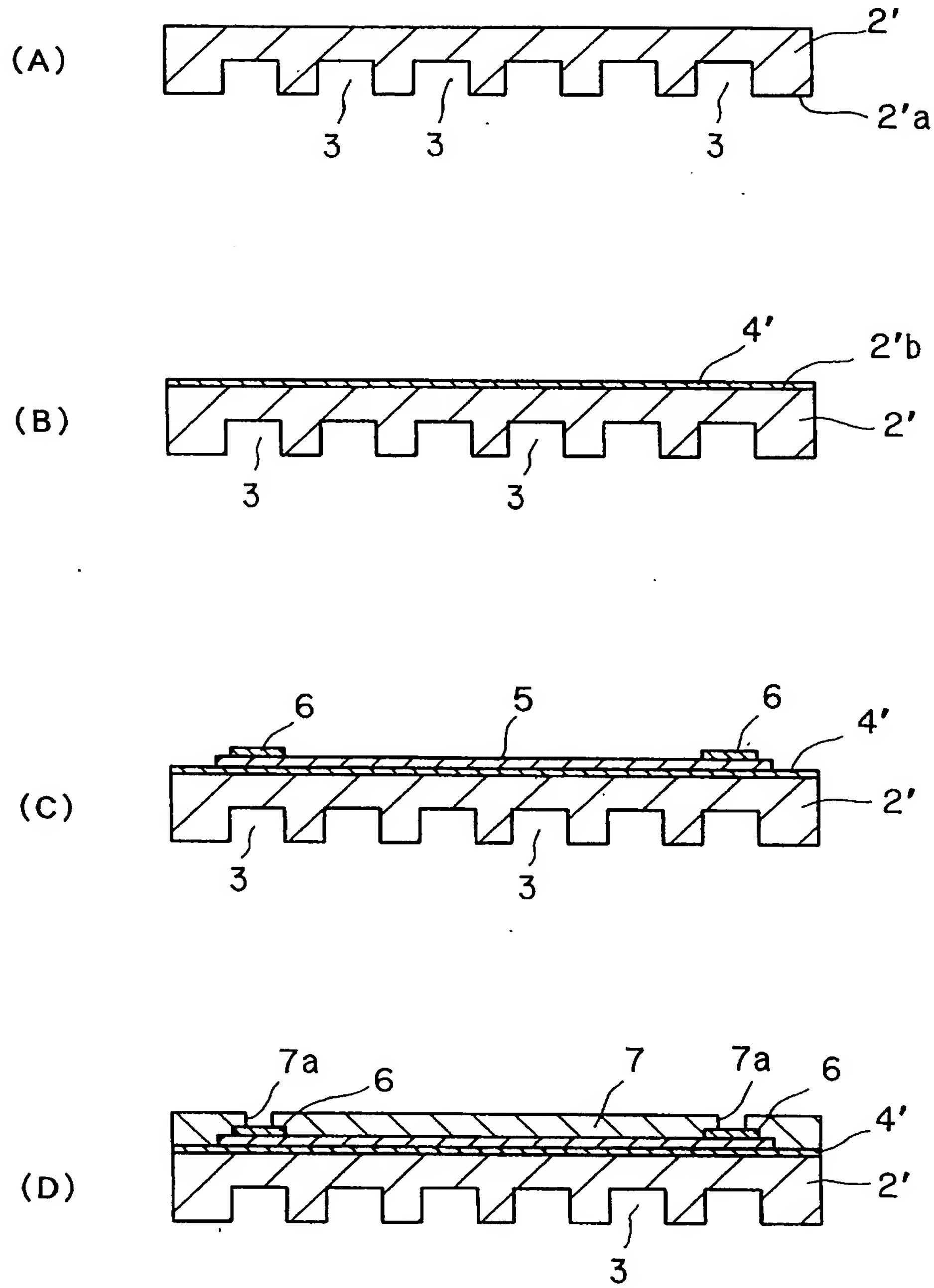


FIG.6

[Fig.7]



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[Fig.8]

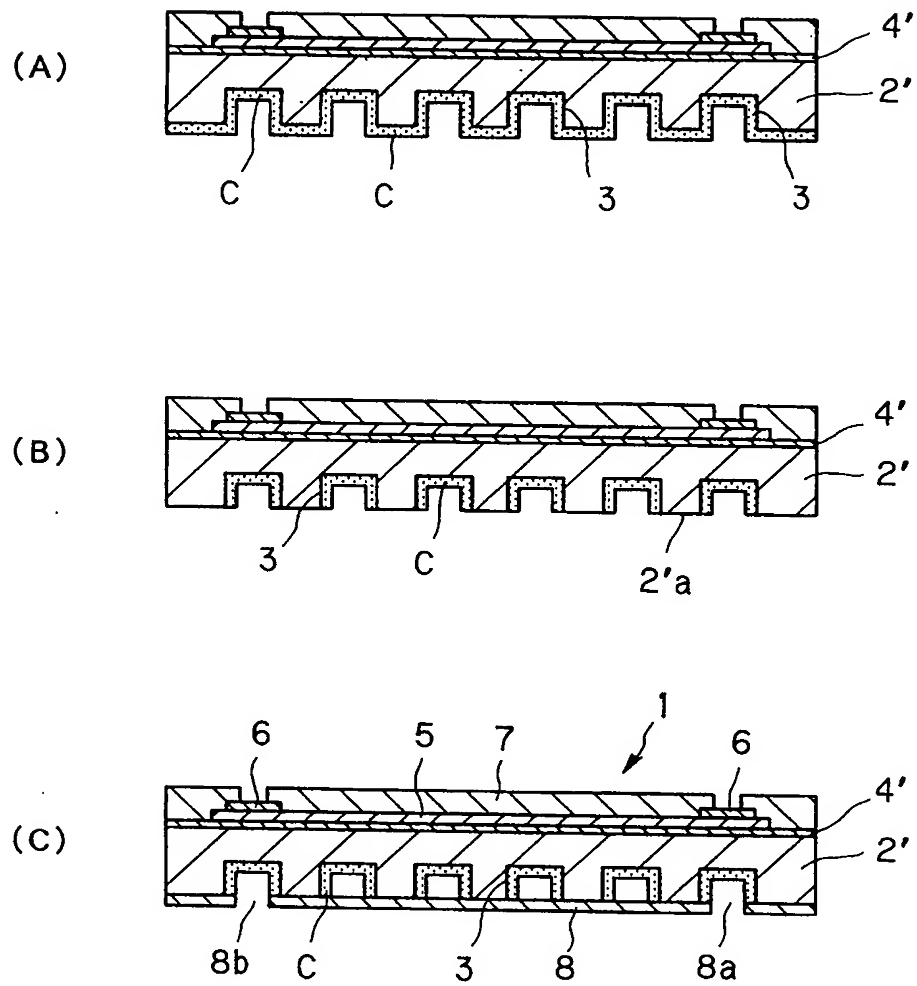

FIG.8

[NAME OF DOCUMENT] Abstract

[ABSTRACT]

[PROBLEM]

To provide a microreactor that enables a small-sized and highly-efficient reformer for hydrogen production, and a production method that can easily produce such a microreactor.

[SOLVING MEANS]

A microreactor is configured to have a metal substrate having a microchannel portion on one surface thereof, a heater provided on the other surface of the metal substrate via an insulating film, a catalyst supported on the microchannel portion, and a cover member having a feed material inlet and a gas outlet and joined to the metal substrate so as to cover the microchannel portion. Since the microreactor uses the metal substrate having a high thermal conductivity and a small heat capacity, the efficiency of heat conduction from the heater to the supported catalyst becomes high, and the processing of the metal substrate is easy to facilitate the production.

[SELECTED DRAWING] Fig. 2

I, Junzo YONEDA of 4F, Matsui Building, 28-2, Tomiyamacho, Kanda, Chiyoda-ku, Tokyo 101-0043 Japan, do hereby certify that I am conversant with the English and Japanese languages and am a competent translator thereof, and I further certify that to the best of my knowledge and belief the foregoing is a true and correct translation made by me of the priority document of Japanese Patent Application No. 2003-313535.

Signed this 5th day of February, 2010

Junzo Yoneda

(Junzo YONEDA)